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PRELIMINARY
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STREAMFLOW AND WATER QUALITY IN THE LOWER BIG HOLE RIVER

SUMMER 1977

JUN 1 9 1999

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Water Quality Specialist
Statewide 208 Project

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Water Quality Bureau
Environmental Sciences Division
Montana Department of Health and Environmental Sciences
February 1978

JUN 1 9 1995

INTRODUCTION

This report records changes in selected water quality parameters during the 1977 irrigation season on the lower Big Hole River near Twin Bridges, Montana. The effects of dewatering[1] are described in terms of biological diversity, biological productivity, and the fitness of remaining water for instream and diverted uses.

Calendar year 1977 began with the lowest snowpacks on record for some areas of southwestern Montana. Streamflow was below normal over much of the state and many reservoirs could not be filled to capacity. Warnings of impending drought were circulated and energy officials recommended emergency measures to ease forecasted hydroelectric shortages.

Along the Big Hole River, irrigators began diverting water in April, which was well before the usual start of the irrigation season in this high mountain valley. Based on past performances during dry years, personnel from the Water Quality Bureau predicted complete dewatering at one or more points on the lower "Blue Ribbon" section of the Big Hole River during the summer of 1977. Thus, the Water Quality Bureau decided to commit a fraction of its Statewide 208 water quality monitoring budget to a combined cinematic/technical documentation of water quality impacts due to dewatering on the lower river.

The Big Hole River did not go dry in 1977. The lowest recorded flow from April through September was 4.90 m^3 (173 cfs) at the USGS station near Melrose. Nevertheless, this report and its companion film ("Man and Water") have identified the kinds of water quality impacts due to dewatering and the directions various parameters take in response to declining streamflow.

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[1] In the context of this report, "dewatering" means the removal of water from a stream to the point that some beneficial use is impaired.

LAND USE AND WATER QUALITY

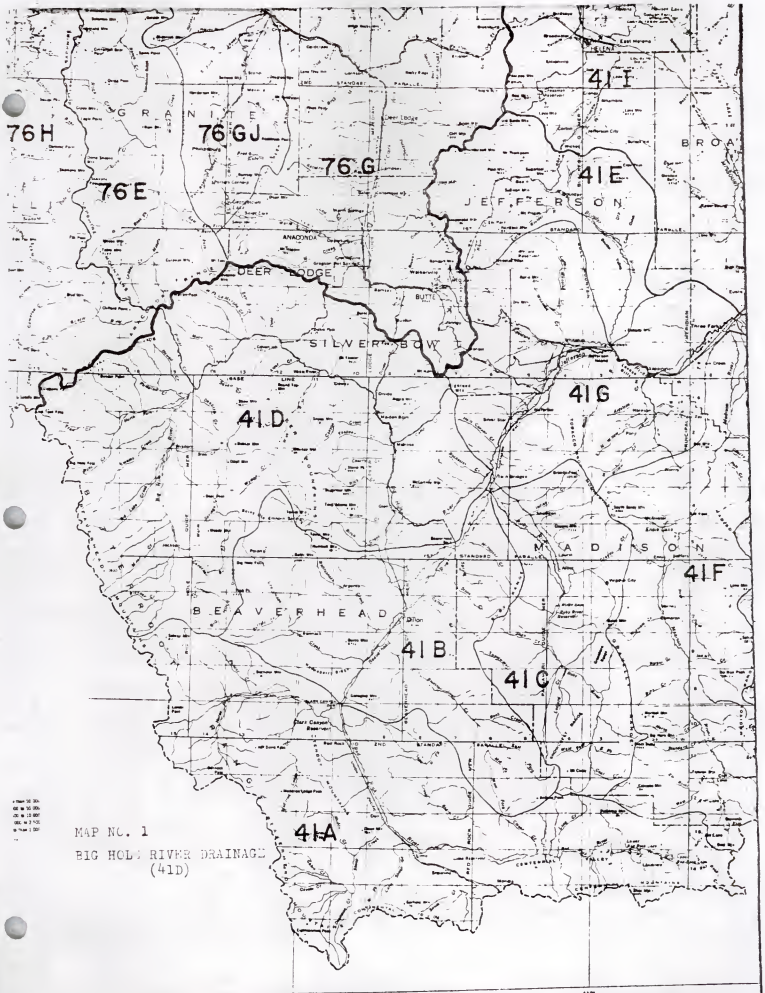
The Big Hole River (Map 1) begins in the forested Bitterroot Range in southwestern Montana at an elevation of about 3,200 meters (10,500 feet). It flows generally eastward through broad, grassy, sparsely peopled valleys and narrow canyons for 185 kilometers (115 miles). At 1,400 meters (4,600 feet) elevation near the town of Twin Bridges, it meets the Ruby and Beaverhead rivers to form the Jefferson, which is one of the three main tributaries of the Missouri River.

The area drained by the Big Hole River is 6,413 km^2 (2,476 square miles) (U.S.G.S., 1976). Cattle grazing is the primary industry, with 550 km^2 (212 square miles) of land above Melrose devoted to irrigated hay and pasture for supplemental winter feeding of livestock. The lower river, from the mouth to the old dam above the town of Divide, is a nationally recognized recreational trout fishery.

The Montana Department of Health and Environmental Sciences (1975) has summarized water quality in the Big Hole River as follows:

> The Big Hole River generally is an excellent quality, moderately hard, calcium-bicarbonate type water with low turbidity and low sulfate, sodium, chloride, and toxic metals concentrations. However, stream temperatures considered adverse for growth and propagation of salmonids and associated aquatic life have been recorded downstream of the U.S.G.S. station near Melrose, Montana. Temperature fluctuations appear somewhat cyclic and may be affected by diversion for irrigation. Miller (Montana Department of Fish and Game) reports the number of irrigation diversions between Divide Dam and the mouth of the Big Hole River increased from 26 in 1970 to 44 in 1973. The Big Hole River near Twin Bridges, Montana was dry for a period of time during the summer of 1966 (Wipperman, Montana Department of Fish and Game). Secondary effects of channelization and construction of diversion works for irrigation are an increase in stream sediment loads and turbidities.

Since enactment of the Water User Act in 1973, the Montana Department of Natural Resources and Conservation has issued two permits for diversion



MAP NO. 1

BIG HOLE RIVER DRAINAGE
(41D)

from the Big Hole and seven permits for diversion from tributary streams. Both diversions on the mainstem are for irrigation downstream from Melrose and total 0.29 m^3/s (10.25 cfs)(Kindle, 1978).

STUDY SITES

Water quality data were collected at the bridge on the county road west of Twin Bridges (T.3S, R.6W SEC. 29ADCB), locally known as Seidensticker Bridge (Map 2). Three occasional measurements of instantaneous flow were made at this location by Water Quality Bureau personnel. The mean daily flows presented in this report were measured by the U.S.G.S. (United States Geological Survey, Water Resources Division, Helena) at their surface water station No. 06025500 near Melrose (Map 3). This site is approximately 28 river miles (45 kilometers) upstream from Seidensticker Bridge.

WATER QUALITY APPROACHES

Three approaches were taken in measuring water quality response to changes in streamflow: physical, chemical, and biological.

Physical measurements included temperature, conductivity, and turbidity. Temperature was measured at two-hour intervals with a recording thermograph operated by the Montana Department of Fish and Game.[1] The temperature record for the Seidensticker Bridge site runs from May 27 to September 17, 1977, with a gap from August 14 to 28 due to vandalism of equipment. Conductivity and turbidity were measured twice monthly from June through August by the Chemistry Laboratory, Montana Department of Health and Environmental Sciences.

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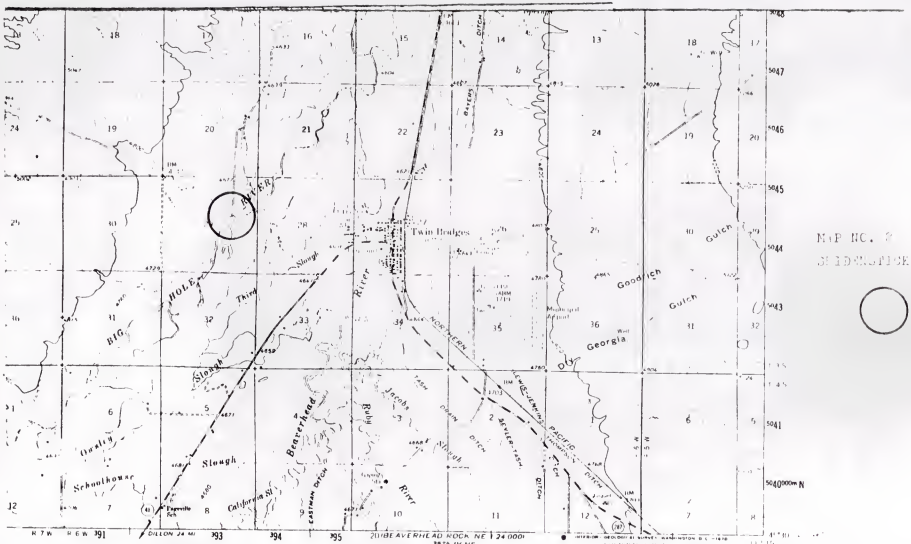
[1]Temperature data were provided by Mr. Jerry Wells, Montana Department of Fish and Game, Dillon.



MAP NO. 2

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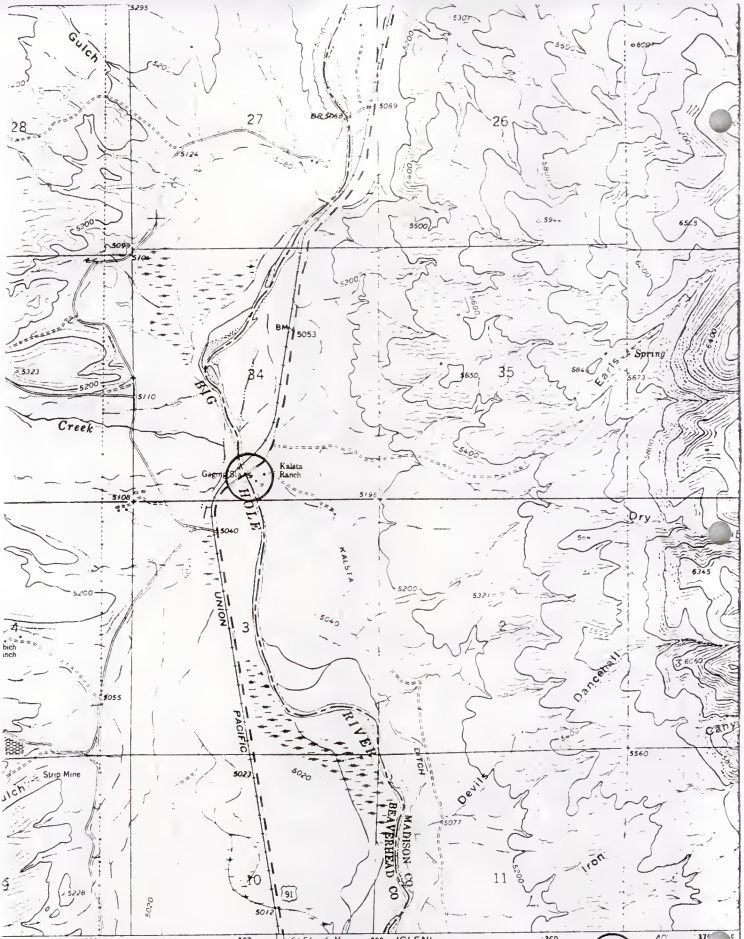
Gulch
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BM
Big Hole
Creek
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Ears Spring
Kalsta Ranch
Gas Well
5040
KALSTA
UNION
PACIFIC
3
2
Dry
Dancehall
Canyon
4
Strip Mine
5055
5021
5000
RIVER
DITCH
MADISON CO
BEAVERHEAD CO
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MAP NO. 3 USGS SURFACE WATER STATION NO. 06025500

Selected chemical constituents were also measured twice monthly at the Chemistry Laboratory in Helena. These were pH, sum of dissolved ions, total hardness, total alkalinity, sodium adsorption ratio, common cations and anions, and algal nutrients. Methods used by the laboratory for chemical and physical analyses will be supplied on request.

One 24-hour dissolved oxygen series was run using the azide modification of the Winkler method. This was completed on August 4 and 5. Dissolved oxygen was measured at 4-hour intervals beginning at 10 a.m.

Three biological approaches were attempted: chlorophyll and biomass accrual on artificial substrates (to measure instream algal growth rate or eutrophication potential), algal collections from natural substrates, and benthic invertebrate collections from natural substrates. Chlorophyll and biomass samples were improperly stored and the chlorophylls exceeded the recommended holding time prior to analysis; consequently, they could not be used.

Bentnic algae (periphyton) and invertebrates (benthos) were collected four times over the course of the study. Changes in biological diversity and indicator taxa often reflect changes in water quality. Sampling and enumeration methods are available on request from the author. Invertebrate taxa were identified by Mr. Gary Ingman of the Water Quality Bureau.

STUDY RESULTS

Streamflow

Mean daily discharges at the U.S.G.S. station near Melrose are presented in Table 1. Peak discharge for the period April through September 1977 was 131.11 m^3/s (4630 cfs) on June 12. The lowest flow recorded was 4.90 m^3/s (173 cfs) on September 14. Total yield

for the 1977 water year (October 1976 through September 1977) was 613 cubic hectares (497,600 acre-feet). The average annual yield for 52 years of record at this station is 1,026 cubic hectares (832,500 acre-feet).

Instantaneous streamflow at Seidensticker Bridge is compared below with mean daily discharge near Melrose on the three dates that measurements were made at both stations:

Date	Δ	Streamflow (m^3/s)	
		Melrose (U.S.G.S.)	Seidensticker (W.Q.B
July 22	7.82	15.26	7.44
August 4	2.64	11.38	8.74
September 2	3.12	8.61	5.49

Discharge was significantly greater on all three dates near Melrose, therefore it can be assumed that the measurements taken at the U.S.G.S. station (Table 1) were substantial over estimates of discharge at Seidensticker Bridge. This would be expected during the irrigation season because ".....large diversions from Melrose downstream significantly reduce stream flows in the lower river." (Braico and Botz, 1975).

Physical Parameters

Daily maximum and minimum temperatures at Seidensticker Bridge are listed in Table 2. A maximum temperature of 23.4°C was recorded on August 18 and 20. The Environmental Protection Agency Water Quality Criteria "Blue Book" (E.P.A., 1973b) identifies 23.5°C as the ultimate upper lethal temperature for brown trout. This source also gives the temperature range for optimum growth of brown trout as 8 to 17°C. The upper limit of this range (17°C) was exceeded by the minimum daily water temperature at Se[illegible]er

TABLE 1. Mean Daily Discharges (m^3/s) at the U.S.G.S. Surface Water Station (No. 06025500) near Melrose. (Courtesy U.S.G.S., Water Resources Division, Helena)

DAY	APR	MAY	JUN	JUL	AUG	SEP
1	10.76	34.26	37.38	16.08	13.96	8.30
2	10.56	35.96	42.48	15.77	13.11	8.61
3	10.17	36.25	43.33	15.89	12.32	8.84
4	10.93	32.00	43.33	17.36	11.38	8.30
5	11.95	26.59	49.84	19.17	11.04	7.65
6	14.92	23.79	52.67	20.95	11.13	6.99
7	20.50	22.23	57.48	22.20	11.47	6.37
8	28.60	21.01	60.88	21.95	11.44	6.06
9	49.27	20.19	63.71	20.81	11.02	5.78
10	55.22	20.70	75.61	21.92	10.99	5.64
11	46.16	21.55	112.99	24.55	12.12	5.66
12	41.63	20.73	131.11	25.88	11.19	5.38
13	39.64	19.11	117.52	24.81	9.71	5.04
14	37.66	18.80	92.60	22.85	8.84	*4.90
15	30.58	23.33	88.07	21.46	8.41	5.04
16	29.17	21.83	87.78	19.62	7.76	4.98
17	32.85	20.13	74.76	18.01	7.39	5.97
18	32.56	19.79	62.30	15.63	6.46	7.93
19	30.58	22.74	50.40	14.07	6.12	9.85
20	27.38	28.32	45.02	14.70	5.83	12.06
21	25.77	32.56	45.87	14.89	4.93	12.94
22	25.88	28.88	44.18	15.26	5.04	14.44
23	28.32	27.75	38.51	16.20	5.38	14.98
24	33.70	29.45	33.41	15.46	5.69	15.12
25	37.66	43.04	29.17	17.67	5.97	15.35
26	40.49	63.15	26.08	23.39	5.97	15.09
27	41.63	66.83	23.14	30.02	5.92	14.81
28	38.51	57.77	20.53	24.47	6.00	14.44
29	35.40	49.27	18.75	20.33	6.37	14.67
30	34.55	44.74	16.76	17.16	6.68	16.99
31	-	39.93	-	15.04	7.62	-

*Minimum Recorded Flow

...AND MINIMUM TEMPERATURES (°C) IN THE BIG HOLE RIVER AT SIDENSTICKER BRIDGE, 19
(Courtesy Montana Department of Fish and Game)

DAY	MAX	MIN	DAY	MAX	MIN	DAY	MAX	MIN	DAY	MAX	MI
y 27	11.9	10.0	June 24	22.0	16.9	Aug 3			Aug 31	15.2	10.
28	11.4	9.6	b 25	22.3	17.4	4			Sep 1	17.9	12.
29	11.9	8.6	b 26	22.6	17.5	5	19.2		2	19.2	12.
30	13.8	9.3	b 27	22.3	17.4	6	19.9	15.0	3	18.7	13.
31	16.5	11.3	28	22.4	16.2	7	22.2	15.9	4	19.9	13.
ne 1	18.9	13.8	29	21.7	16.7	b 8	19.8	17.1	5	20.7	14.
2	18.2	14.3	30	22.3	15.3	9	19.9	15.1	6	21.3	14.
3	17.5	13.6	July 1	21.2	16.0	10	20.0	14.2	7	19.8	14.
4	19.4	15.1	2	19.4	16.3	11	21.1	14.0	8	18.3	14.
5	20.1	15.6	3	17.5	14.2	12	22.1	15.3	9	18.3	11.
6	20.3	16.6	4	14.7	13.9	13	22.1	16.4	10	18.5	12.
7	19.2	15.9	5	19.5	12.0	14	20.6	16.4	11	18.1	12.
8	17.9	15.6	6	19.7	14.1	15	21.1	15.6	12	18.3	12.
9	15.2	14.9	7	19.9	13.2	16	21.8	15.8	13	18.5	12.
10	13.2	12.9	8	20.5	14.7	17	22.2	16.2	14	17.3	12.
11	13.4	11.5	9	20.0	15.3	a,b 18	23.4	17.5	15	15.6	13.
12	14.6	11.1	10	20.3	15.0	b 19	22.7	17.1	16	14.8	11.
13	15.6	13.0	11	20.1	15.0	a,b 20	23.4	17.2	17	-	10.
14	16.6	14.0	12	20.4	15.9	21	21.9	16.8			
15	17.6	13.2	13	20.6	15.8	22	19.0	16.5			
16	15.9	13.9	14	-	15.3	23	22.2	14.8			
17	17.6	13.1				24	18.3	15.5			
18	18.5	13.9	28	21.7	-	25	17.8	14.3			
19	19.2	15.1	29	21.3	16.8	26	16.4	13.5			
20	18.9	16.1	30	21.4	15.5	27	16.3	12.6			
21	18.1	14.8	31	22.2	16.3	28	17.3	12.0			
22	19.1	14.5	Aug 1	23.1	16.8	29	18.3	13.3			
23	20.6	16.2	b 2	23.0	17.1	30	14.3	12.7			

[a] Dates of maximum
corded temperatur
[b] Dates on which th
minimum recorded
perature exceeded
upper limit for o
mum growth of bro
trout (17°C).

sticker Bridge on eight days for which temperature records are available (Table 2).[2]

Conductivity and turbidity values for grab samples from the Seidensticker Bridge site are listed in Table 3. Conductivity tended to increase over the course of the season and turbidity decreased, but none of the values exceeded the recommended criteria for the common water uses. (E.P.A., 1973b).

Chemical Parameters

Values for selected chemical constituents, including algal nutrients, are also presented in Table 3. The pH, sum of dissolved ions, hardness, alkalinity, and individual cations and anions all tended to increase with falling discharge through the summer. None of these trends indicate a significant degradation of water quality. Sodium adsorption ratio (S.A.R.) remained constant at 0.4 throughout the irrigation season.

Algal nutrients, notably biologically available phosphorous (PO_4) and total phosphorous, declined to a midsummer low in July and thereafter remained fairly constant through August and the first part of September. On the other hand, the values for nitrogen species were erratic with biologically available nitrogen (nitrate and ammonia) more often than not below the limit of analytical detection (0.01 mg/l), particularly late in the season. These data indicate active biological uptake of phosphorous until the end of July. Beyond this date, the availability of nitrogen appears to be limiting primary production. Consequently, there is no

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[2] Near Melrose, the U.S.G.S. recorded a maximum daily temperature of 22.1°C on July 23 but on no date did the minimum daily temperature exceed 17°C (provisional data supplied by the Water Resources Division, Helena).

TABLE 3. VALUES OF SELECTED PHYSICAL AND CHEMICAL PARAMETERS FOR GRAB SAMPLES FROM THE SEIDENSTICKER BRIDGE SITE, 1977

	UNIT	6-10	6-23	7-8	7-22	8-4	8-19	9-
ab pH	pH units	7.60	8.10	8.00	8.10	7.90	8.30	
um Dissolved Ions	mg/l	-	155.1	-	207.3	194.8	215.3	21
ab Conductivity	umhos/cm @ 25 C	-	185.6	-	239.0	270.0	283.0	27
otal Hardness	mg/l $CaCO_3$	76	78	-	106	98	112	12
otal Alkalinity	mg/l $CaCO_3$	71	85	-	112	106	113	11
ab Turbidity	JTU	-	1.4	2.0	1.0	0.3	0.3	0.
odium Adsorption Ratio	None	-	0.4	-	0.4	0.4	0.4	0.
alcium	mg/l	20.8	23.2	-	29.7	31.6	31.3	36.
odium	mg/l	-	8.3	-	9.6	10.1	10.2	9.
agnesium	mg/l	5.8	4.9	-	7.8	4.6	8.2	8.
otassium	mg/l	-	-	-	3.6	3.8	4.0	4.
icarbonate	mg/l	86.0	103.0	-	137.0	129.0	137.0	142.
arbonate	mg/l	0.0	0.0	-	0.0	0.0	1.0	0.
ulfate	mg/l	10.0	15.0	-	17.0	11.0	20.0	15.
hloride	mg/l	2.1	0.2	-	3.0	3.7	3.9	4.
hosphate (PO_4 as P)	mg/l	0.027	0.025	0.020	0.013	0.012	0.013	0.
hosphorous (Total as P)	mg/l	0.045	0.038	0.024	0.019	0.026	0.025	0.
$O_3 + NO_2$ (Total as N)	mg/l	0.03	<0.01	0.02	0.04	<0.01	0.01	<0.0
mmonia (Total as N)	mg/l	<0.01	<0.01	0.04	0.01	<0.01	<0.01	<0.0
itrogen, KJL (Total as N)	mg/l	0.36	0.48	<0.05	0.23	0.37	0.34	0.3

significant depletion of phosphate after the first of August.

The results of the 24-hour dissolved oxygen series on August 4-5 are given below:

10 a.m.	8.6 mg/l
2 p.m.	9.2 mg/l
6 p.m.	8.3 mg/l
10 p.m.	7.1 mg/l
2 a.m.	6.8 mg/l
6 a.m.	7.0 mg/l
10 a.m.	8.4 mg/l

The lowest recorded value (6.8 mg/l) is slightly less than the minimum concentration specified for a B-D_1 stream (7.0 mg/l) by the Montana Water Quality Standards (MSDHES, 1974).

Biological Parameters

Table 4 offers relative abundance estimates for the diatom group (Bacillariophyceae) and for non-diatom algal genera in composite periphyton samples taken at Seidensticker Bridge. As in most other Montana streams, the flora consists mainly of green algae and diatoms; blue-green algae were rare and nitrogen-fixing blue-greens were absent. There were more non-diatom genera later in the season (August and December) than during runoff (April and June).

A total of 105 diatom taxa was identified from the four samples; the percent relative abundance (PRA) values for these taxa are listed in Appendix A. Table 5 lists values for selected diatom community parameters on the four sample dates. The consistently high diversity and equitability values and the relatively large number of taxa indicate an unstressed environment favorable for diatom growth. However, diatom di-

versity did decline perceptibly over the course of the irrigation season.

The diatom genus Achnanthes, an indicator of adequate dissolved oxygen (Cholnoky, 1968), consistently represented between 6 and 8 percent of the diatom flora. Nitzschia species, which are known to be favored by elevated nitrogen levels (Cholnoky, 1968), accounted for up to 29 percent of the flora. Nitzschia paleacea, the most common Nitzschia species late in the season (December), depends on organic matter as a nitrogen source, that is, it is an obligate nitrogen heterotroph and is not affected appreciably by nitrate or ammonia concentrations. The peak in PRA of Epithemia sorex in August probably corresponds with the progressive seasonal increases in dissolved solids and temperature. E. sorex is a summer form that is favored by higher alkalinity water (Lowe, 1974).

Overall, the algal flora indicates a cool, semi-hard, moderately enriched, flowing water environment. The structure and composition of the periphyton community suggest that there were probably no significant physical or chemical stresses operating on the dates this community was sampled. However, changes in species composition with time clearly indicate a response to changes in water temperature, salinity, and nutrients.

The relative abundances of benthic invertebrate taxa are estimated in Table 6. The largest number of taxa was found in the August collection. On all dates, the majority of common and abundant taxa represented groups that are known to be sensitive to and intolerant of organic pollution. Most were also typically cold water forms. As with the algae, the invertebrates indicate no significant stress on the biotic community of the Big Hole River during the 1977 irrigation season.

TABLE 4. ESTIMATED RELATIVE ABUNDANCE OF DIATOMS AND NON-DIATOM ALGAL GENERA IN SAMPLES TAKEN FROM NATURAL SUBSTRATES AT SEIDENSTICKER BRIDGE, 1977

DIVISION	GENUS	DATE (1977) 4-26	6-10	8-23	12-20
Chlorophyta (green algae)	Ankistrodesmus			R	R
	Cladophora			A	C
	Closterium	R	C	R	
	Cosmarium	R	C	C	
	Oedogonium				C
	Pediastrum			C	R
	Scenedesmus			C	R
	Spaerocystis			R	
	Spirogyra				R
	Stigeoclonium			C	C
	Ulothrix	C	A	R	C
Cyanophyta (blue-green algae)	Gomphosphaeria			R	
	Oscillatoria				R
	Phormidium				R
	Rivularia			R	
Rhodophyta (red Algae)	Audouinella				R
Chrysophyta Class Bacillariophyceae (diatoms)		A	A	A	A
Total Non-diatom Genera		3	3	11	11

A = Abundant (>40% of sample)

C = Common (5-40% of sample)

R = Rare (<5% of sample)

TABLE 5. SELECTED DIATOM COMMUNITY PARAMETERS FOR PERIPHYTON SAMPLES TAKEN FROM THE BIG HOLE RIVER AT SEIDENSTICKER BRIDGE, 1977

PARAMETER	DATE (1977) 4-26	6-10	8-23	12-20
PRA[1] MAJOR TAXA[2]				
Diatoma vulgare	7.8	21.4	2.0	3.7
Epithemia sorex	7.8	8.4	40.7	14.8
Fragilaria vaucheriae	10.9	3.4	0.3	14.0
Nitzschia paleacea	3.4	4.0	7.9	20.2
Synedra ulna	17.1	15.2	4.0	0.3
PRA[2] Achnanthes SPECIES	7.1	6.2	6.5	7.4
PRA[1] Nitzschia SPECIES	17.6	14.5	19.5	29.0
TOTAL TAXA	76	64	45	40
TAXA COUNTED	47	40	36	29
CELLS COUNTED	322	323	354	351
DIVERSITY ($\bar{d}$)[3]	4.45	4.15	3.58	3.60
EQUITABILITY (e)[4]	0.68	0.65	0.47	0.59

[1] PRA = Percent Relative Abundance

[2] Major Taxa are those that account for 10 percent or more relative abundanc in one or more samples.

[3] $\bar{d} = \frac{C}{N} (N \log_{10} N - \sum n_i \log_{10} ni)$ (E.P.A., 1973a)

[4] $e = \frac{S'}{S}$ (E.P.A., 1973a)

TABLE 6. ESTIMATED RELATIVE ABUNDANCE OF BENTHIC INVERTEBRATE TAXA IN SAMPLES TAKEN AT SEIDENSTICKER BRIDGE, 1977. (THE NUMBER IN PARENTHESES ( ) INDICATES THE PROBABLE NUMBER OF SPECIES.)

			DATE (1977)			
ORDER	FAMILY	GENUS	4-26	6-10[1]	8-23	9-7
Plecoptera (Stoneflies)	Perlodidae	Isoperla	A	C(2)	C	C
	Chloroperlidae	Hastaperla	A	C		
	Perlidae	Acroneuria			A(2)	C(2)
		Claasenia			C(2)	C(2)
	Pteronarcidae	Pteronarcys			A	C
Ephemeroptera (Mayflies)	Baetidae	Baetis	C	C	C	C
		Ephemerella	C	C		
	Heptageniidae	Cinygma		C		C
Hemiptera (True Bugs)	Notonectidae		C			
Diptera (True Flies)	Tipulidae		C(3)		C	
	Chironomidae				C	A
	Rhagionidae	Atherix			A	
	Simuliidae				C	C
Tricnaptera (Caddis flies)	Brachycentridae	Brachycentrus		C	C	
	Leptoceridae	Athripsodes		R	R	C
	Hydropsychidae	Hydropsyche		R	A	A
		Diplectrona			R	
Coleoptera (Beetles)	Elmidae	Cleptelmis		R	R	C
		Rhizelmis			R	
Hydracarina (Water Mites)				C		
Plesiopora (Worms)	Naididae			R		
Total Taxa			8	12	17	13

[1] Summary of four surber square-foot samples; all others kick-net samples.

A = Abundant C = Common R = Rare

DISCUSSION

The first effect of dewatering, even before changes in water quality can be detected, is a reduction of aquatic habitat. Although a great deal has been written concerning the instream flow and habitat needs of fish, the aquatic insects and algae that support fish also have certain habitat needs. Because they are much smaller and more numerous than fish, invertebrates and algae are widely distributed over the river bottom, even to the water's edge. Unlike fish and the larval stages of aquatic insects, which are motile and capable of retreating to deeper water, algae are usually attached to the bottom and therefore totally vulnerable to desiccation.

Some estimates of primary (algal) production in the Big Hole River are available from the Statewide 208 Biological Monitoring Project, which began concurrently with this study. At the Seidensticker Bridge site, biomass accrual on artificial substrates was about 340 milligrams per square meter per day in late August and early September (unpublished data). (This is about equal in productivity to the Yellowstone River near Laurel (Klarich, 1976).) In other words, when one square meter of bottom surface area becomes dry, about one third of a gram of algal production is forfeited for each day of exposure.

This loss of productivity might be more meaningful if converted to potential loss of fish in terms of pounds per acre. This can be calculated roughly if certain assumptions are adopted. (The most important assumption is that energy is transferred from one trophic level to the next with an efficiency of about 10 percent (Odum, 1963).) If these

assumptions are valid, the ultimate loss of fish flesh would be approximately 0.03 pounds for every day an acre of river bottom is exposed. On an annual basis, the loss would be about 11 pounds. This estimated reduction in fish yield would result only from a decline in food supply and would not include other losses that might result from environmental stresses caused by dewatering.

Beyond the initial losses of wetted bottom area and algal production, changes in water quality begin to occur as dewatering progresses. The usual flow pattern for the Big Hole River was considerably affected in 1977 by some timely rains in the basin during the irrigation season. Consequently, the effects of low, late summer streamflows on water quality were subdued. Nevertheless, the kinds of impacts can be ascertained along with the directions that affected parameters will take and the limits that they will approach if extrapolated to historical extreme low flows.

Perhaps the next most biologically damaging impact of dewatering on the Big Hole is elevated temperature. Water temperature at the U.S.G.S. surface water station near Melrose normally peaks around the first of August (Aagaard, 1969). In 1977, a maximum of 22.1°C was reached at this site on July 23. Temperature records at Seidensticker Bridge were not available from July 15 through 27 because of vandalism to equipment; the maximum recorded temperature (23.4°C) occurred here later in August. The maximum temperatures recorded in this study did not exceed the level known to be ultimately lethal to brown trout (23.5°C), although higher temperatures have been recorded in the past (Braico and Botz, 1975). Maximum daily temperatures that exceeded the upper limit for optimum growth of brown trout (17°C) were recorded almost consecutively from the first of June to the middle of September. Minimum daily temperatures that

exceeded this optimum were recorded on seven days during this same period.

Unpublished data provided by the U.S. Bureau of Reclamation (Field Planning Branch, Billings) show that irrigation return water in the Big Hole Basin is consistently higher in conductivity than diverted water. Average conductance of diverted water was about 170 (μmhos/cm) in 1974 and 1975, whereas the average conductance of return water was about 320 for the same two years. The increase in electrical conductance of Big Hole River water during the 1977 irrigation season--from 186 μmhos/cm to 283 μmhos/cm--probably reflects the influence of irrigation return flows. Although this registered increase in salinity may have some subtle effects on the composition of the river's algal community, it should pose no hazzard to irrigated plants. The very low S.A.R. value (0.4) confirms the safety of Big Hole water for irrigation purposes.

The increases in other common chemical parameters (calcium, sulfate, etc.) are not significant in themselves and simply help to trace the parallel increase in salinity. Certain parameters, such as pH and alkalinity, reflect increasing biological activity in the river as the season progresses. The most telling indicators of biological activity are changes in algal nutrient and dissolved oxygen concentrations.

The lower Big Hole River appears to become nitrogen limited as nitrate and ammonia are depleted in August. (However, there is some evidence that the remaining pool of organic nitrogen (measured by the Kjeldahl method) is used by nitrogen heterotrophic diatoms such as Nitzschia paleacea.) During this period of inorganic nitrogen depletion, the daily chlorophyll a accrual (net production) rate was 1.52 mg/m^2 (unpublished data; Biological Monitoring Project). This is still a

respectable growth rate when compared to other Montana rivers (Klarich, 1976) and indicates what may be considered as mesotrophic conditions. Although the river cannot now be called eutrophic, there appears to be a potential for significant increases in algal growth with cultural additions of nitrogen.

The moderate late summer algal growth in the river did not appear to significantly accentuate the nighttime oxygen sag measured on August 4 and 5. Nevertheless, with further reductions in streamflow, additions of nitrogen, and increases in temperature, nightly dissolved oxygen levels could become critical for the well-being of sensitive aquatic organisms. The present dissolved oxygen situation in the Big Hole River cannot be appraised on the basis of only one 24-hour series of measurements.

None of the algae identified from the Big Hole River are known nitrogen-fixers. Consequently, the algae growing in the river in late summer and fall must be using stored N or organic N, or else they are capable of extracting soluable inorganic nitrogen from the water at extremely low ambient concentrations. Among the diatoms, Nitzschia paleacea is a nitrogen heterotroph, which may explain why it prospered late in the season. The algae Cladophora and Stigeoclonium indicate moderate and considerable nutrient enrichment, respectively. They were common to abundant in samples from the Big Hole when inorganic nitrogen was essentially depleted. One possible explanation might be that these algae were taking up inorganic nitrogen as quickly as it was being converted from the organic pool by the process of nitrification.

Intensified competition for available nitrogen in late summer and fall may have been partly responsible for the greater diversity of non-

diatom algae at this time. Other factors, primarily light and water temperature, also control algal periodicity and were probably involved as well. Certain genera, including Audouinella and Oedogonium, are typically found only in the cooler months. Others, like Cladophora and Ulothrix have definite seasonal cycles triggered by light and temperature.

Three of the major diatom taxa from the Big Hole--Diatoma vulgare, Fragilaria vaucheriae, and Synedra ulna-- are "eutrophic" species preferring low light and low water temperatures (Lowe, 1974). They peaked in relative abundance in spring and late fall with minima in August. (S. ulna had its lowest relative abundance in December and its second lowest in August). Epithemia sorex, which peaked in August, prefers high conductivity water rich in calcium (Patrick and Reimer, 1975). Nitzschia paleacea, whose organic nitrogen requirements have been discussed earlier in this paper, increased to a maximum abundance in December, thus accounting for the peak in total Nitzschia species in this month. The stability of oxygen-loving Achnanthes sp. indicated adequate dissolved oxygen through the summer , confirming the results of the 24-hour D.O. series.

For unpolluted waters, diatom diversity ($\bar{d}$) usually varies between 3 and 4 (E.P.A., 1973a). The minimum diatom diversity value at Seidensticker Bridge was 3.58, indicating no appreciable stress on the periphyton community when this sample was collected in August. Equitability (e), which is considered more sensitive to stress than diversity, varies between 0.6 and 0.8 in clean waters, 0.3 to 0.5 in slightly degraded waters, and less than 0.3 in more severely polluted waters (E.P.A., 1973a).

The values for e in August and December, 0.47 and 0.59 respectively, indicate a slight stress on the aquatic community. This stress could be temperature, salinity, or nutrient related, or due to any combination of these factors. The exceptional prosperity of E. sorex and Nitzschia paleacea probably had a great deal to do with the relatively low $\bar{d}$ and e values for these two months.

The benthic invertebrate samples from the Big Hole River were dominated by pollution-sensitive, clean water taxa. Although more taxa were collected in late summer than any other time, this may have been an artifact of sampling. Spring samples may have missed some of the very small, immature instars which could easily pass through the net of the sampling device. As they matured and grew in size, more and more would be captured. Late summer hatches could once again deplete the number and variety of catchable organisms, thus reducing the number of taxa. To iterate, the invertebrates indicate no significant stress on tne biota of the Big Hole River during the 1977 irrigation season.

CONCLUSIONS

1. The lower Big Hole River did not become critically dewatered during the 1977 irrigation season, although potentially serious water quality problems did begin to appear.
2. The most serious result of depleted streamflow in 1977 was the loss of wetted river bottom, calculated to result in a loss of roughly 11 pounds of fish per acre exposed per year of exposure.
3. Temperature and perhaps dissolved oxygen in the lower Big Hole River

commonly approach or exceed standards and recommended criteria for the protection of aquatic life in a B-D_1 stream.

4. The Big Hole River is nitrogen limited during the summer irrigation season and further cultural additions of inorganic nitrogen to the river would probably encourage algal growth; coupled with reductions in streamflow and increases in temperature, nightly dissolved oxygen levels could become critical for the well-being of sensitive aquatic organisms.

RECOMMENDATIONS

1. The Department of Natural Resources and Conservation should not authorize additional diverted water use permits for the Big Hole River or its tributaries without first assuring adequate instream flows by means of offstream storage and/or instream flow reservations.
2. The Statewide 208 Program should investigate and recommend irrigation practices that would reduce the quantity of water that is removed from the river and its tributaries.
3. The Water Quality Bureau should watch streamflows in the lower Big Hole River and be prepared to monitor for flow, temperature, dissolved oxygen and biological parameters in the event discharge falls below 100 cfs (2.83 m^3/s) during the irrigation season.

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APPENDIX A. Percent relative abundance (PRA) values for diatom taxa identified from periphyton samples taken at Seidensticker Bridge.

	DATE			
	4-16-77	6-10-77	8-23-77	12-20-77
Achnanthes exigua Grun.			+	
Achnanthes lanceolata (Breb.) Grun.	3.1	1.6	1.7	0.6
A. lanceolata var. dubia Grun.	+	+	0.3	
A. lanceolata var. ?	+			
A. marginulata Grun.				+
A. minutissima Kutz.	4.0	4.6	4.5	6.0
Amphora ovalis (Kutz.) Kutz.	0.3			
A. ovalis var. affinis (Kutz.) V.H. ex De.	0.3		+	+
A. perpusilla (Grun.) Grun.		+		
Anomoeoneis subaerophora (Ehr.) Pfitz.	+			
Caloneis bacillum (Grun.) Cl.			+	+
Cocconeis fluviatilis Wallace	+			
C. pediculus Ehr.	+	+	1.4	+
C. placentula Ehr.	1.6	2.8	4.0	3.4
Cyclotella meneghiniana Kutz.	1.2	0.3	2.0	0.3
Cymatopleura solea (Breb. & Godey) W. Sm.	+	+		+
Cymbella affinis Kutz.	+			
C. lunata W. Sm.	+			+
C. mexicana (Ehr.) Cl.	+	+	+	0.3
C. minuta Hilse ex Rabh.	5.9	3.4	1.1	3.4
C. minuta var. silesiaca (Bleisch ex Rabh.) Reim. comb. nov.	0.3			
C. prostrata var. auerswaldii (Rabh.) Reim. comb. nov.				+
C. sinuata Greg.	0.6	+	0.6	+
Diatoma hiemale var. mesodon (Ehr.) Grun.	0.9			
D. vulgare Bory	7.8	21.4	2.0	3.7
Epithemia sorex Kutz.	7.8	8.4	40.7	14.8
E. turgida (Ehr.) Kutz.		1.2	1.7	0.3
E. turgida var. westermannii (Ehr.) Grun.	+		0.3	
Fragilaria bicapitata A. Mayer		+		
F. brevistriata Grun.	3.7	4.0	0.6	0.8
F. construens (Ehr.) Grun.	+	+		+
F. construens var. binodis (Ehr.) Grun.		+	1.1	
F. construens var. venter (Ehr.) Grun.	3.4	5.6	4.5	5.4
F. crotonensis Kitton.	1.6	0.3		

APPENDIX A. Continued

	4-26-77	6-10-77	8-23-77	12-20-77
Fragilaria pinnata Ehr.		0.3	0.3	
F. vaucheriae (Kutz.) Peters	10.9	3.4	0.3	14.0
F. sp.	0.9			
Gomphoneis herculeana (Ehr.) Cl.	+	0.3	0.8	0.6
G. herculeana var. robusta (Grun.) Cl.	0.3		0.6	
Gomphonema angustatum (Kutz.) Rabh.		+		
G. olivaceum (Lyngb.) Kutz.	0.6	0.3		
G. olivaceum var. calcarea (Cl.) Cl.		0.3		
G. parvulum Kutz.	+		+	
G. tergestinum (Grun.) Fricke		+		
G. ventricosum Greg.	0.3	0.3	0.6	
G. sp.			1.1	
Hannaea arcus (Ehr.) Patr.	+	+		
Hantzschia amphioxys (Ehr.) Grun.	0.3			
Melosira distans (Ehr.) Kutz.	0.3	+		
M. italica (Ehr.) Kutz.	0.3	1.2		
M. varians Ag.	0.3			
Meridion circulare (Grev.) Ag.	0.3			
Navicula accomoda Hust.	+			
N. arvensis Hust.	0.3	+	0.3	
N. aurora Bov.	+			t
N. canitata Ehr.	+			
N. cryptocenhala Kutz.	0.6	1.6	3.4	0.6
N. cryptocenhala var. exilis (Kutz.) Grun.		+	0.6	
N. cryptocenhala var. veneta (Kutz.) Rabh.	1.2	1.9	1.4	0.3
N. cuspidata (Kutz.) Kutz.	+			
N. decussis Östr.	+		t	
N. minima Grun.		0.6		
N. notha Wallace		+		
N. permarva Hust.			+	
N. protracta Grun.	+			
N. pupula Kutz.	0.3	0.3		
N. rhynchocenhala Kutz.		+		
N. rhynchocephala var. germanii (Wallace) Patr. comb. nov.	0.3			
N. rotaeana (Rabh.) Grun.	+	0.3		
N. tripunctata (O. F. Mull.) Bory	0.6	1.2	0.3	0.6

	4-26-77	6-10-77	8-23-77	10-20-77
Navicula viridula var. avenacea (Breb. & Grun.) V. H.	+			
N. sp.				0.3
Neidium iridis var. amphigomphus (Ehr.) A. Mayer	+			
N. iridis var. ampliatum (Ehr.) Cl.		0.3		
Nitzschia acicularis (Kutz.) W. Sm.	0.6	0.3	+	
N. acuta Hantz.		0.3		
N. dissipata (Kutz.) Grun.	1.2	0.6		0.8
N. epiphytica			0.3	
N. fonticola Grun.	1.2			0.8
N. frustulum Kutz.	2.8	6.2	2.1	4.0
N. frustulum var. subsalina Hust.	1.2	0.9	1.1	2.3
N. kutzingiana Hilse	0.3		0.3	
N. linearis (Ag. ex. W. Sm.) W. Sm.	+	+		0.3
N. palea (Kutz.) W. Sm.		+	0.3	
N. paleacea Grun.	3.4	4.0	7.9	20.2
N. recta Hantz.	0.3			
N. romana Grun.	0.6	1.6	2.5	0.3
N. sigmoidea (Ehr.) W. Sm.		+		
N. vermicularis (Kutz.) Hant.		+		
N. sp.		0.6		0.3
Pinnularia borealis Ehr.	+	+		
P. globiceps var. krookei Grun.	0.3			
Rhoicosphenia curvata (Kutz.) Grun.	0.6	0.3	0.3	0.6
Rhopalodia gibba (Ehr.) O. Mull.	0.3			
R. gibba var. ventricosa (Kutz.) H. & M. Perag.				+
Stephanodiscus minutus Cl. & Moll.	+	0.6		
Surirella angustata Kutz.	+	+		
S. ovata Kutz.	0.9	0.3		
Synedra delicatissima W. Sm.		0.3	+	
S. mazamaensis Sov.	2.2	1.9	0.3	14.0
S. minuscula Grun.		0.3		
S. ulna (Nitz.) Ehr.	17.1	15.2	4.0	0.3
S. ulna var. contracta Østr.	X	X		
S. sp.	0.3			0.3
Tetracyclus sp.	+			